

CLAIMS

What is claimed is:

1           1.    A multi-stage intensifier adapted for a fluid  
2 injector comprising:

3           a fluid injection pump piston adapted to pressurize  
4 injection fluid when moved in a first direction;

5           a first intensifier piston positioned to apply force to  
6 the fluid injection pump piston in the first direction  
7 responsive to the pressure of an actuating fluid against an  
8 effective area of the first intensifier piston;

9           a second intensifier piston positioned to apply force to  
10 the fluid injection pump piston in the first direction  
11 responsive to the pressure of an actuating fluid against an  
12 effective area of the second intensifier piston; and,

13          a control valve coupled to selectively apply actuating  
14 fluid pressure to any of at least two of:

15               i)    the effective area of the first intensifier  
16 piston,

17               ii)   the effective area of the second intensifier  
18 piston, and

19               iii) the effective area of both the first and  
20 second intensifier pistons.

1           2.    The multi-stage intensifier of claim 1, wherein the  
2   control valve is coupled to selectively apply actuating fluid  
3   pressure to either:

4           i)    the effective area of the first intensifier piston,  
5   or

6           ii)   the effective area of both the first and second  
7   intensifier pistons.

1           3.    The multi-stage intensifier of claim 2, wherein the  
2   control valve comprises a three position, four way valve.

1           4.    The multi-stage intensifier of claim 2, wherein the  
2   control valve comprises two, two-position, three-way valves.

1           5.    The multi-stage intensifier of claim 1, wherein the  
2   first and second intensifier pistons are coupled together and  
3   wherein the control valve is coupled to selectively apply  
4   actuating fluid pressure to any one of:

5           i)    the effective area of the first intensifier piston,

6           ii)   the effective area of the second intensifier  
7   piston, and

8           iii)  the effective area of both the first and second  
9   intensifier pistons.

1           6.    The multi-stage intensifier of claim 5, wherein the  
2   control valve comprises two, two-position, three-way valves.

1           7.    The multi-stage intensifier of claim 6, wherein the  
2   three-way valves are magnetically latchable spool valves  
3   using residual magnetism.

1           8.    The multi-stage intensifier of claim 1, wherein the  
2   actuating fluid is selected from the group of fuel, engine  
3   oil and hydraulic fluid and the injection fluid is fuel.

1           9.    A fluid injector having a multistage intensifier  
2   comprising:

3           an injector adapted to inject fluid responsive to the  
4   pressurization of an injection fluid;

5           a fluid injection pump piston adapted to pressurize  
6   injection fluid when moved in a first direction;

7           a first intensifier piston positioned to apply force to  
8   the fluid injection pump piston in the first direction  
9   responsive to the pressure of an actuating fluid against an  
10   effective area of the first intensifier piston;

11          a second intensifier piston positioned to apply force to  
12   the fluid injection pump piston in the first direction  
13   responsive to the pressure of an actuating fluid against an  
14   effective area of the second intensifier piston; and,

15          a control valve coupled to selectively apply actuating  
16   fluid pressure to any of at least two of:

17           i)    the effective area of the first intensifier  
18       piston,  
19           ii)   the effective area of the second intensifier  
20       piston, and  
21           iii) the effective area of both the first and  
22       second intensifier pistons.

1       10.   A method of operating a fuel injector having a  
2       multi-stage intensifier, comprising:  
3       providing a fuel injection pumping piston adapted to  
4       pressurize injection fuel when hydraulically moved in a first  
5       direction;  
6       providing a first effective area of the multi-stage  
7       intensifier responsive to an actuating fluid pressure to move  
8       the injection fuel pumping piston in the first direction;  
9       providing a second effective area of the multi-stage  
10      intensifier responsive to an actuating fluid pressure to move  
11      the injection fuel pumping piston in the first direction, the  
12      first and second effective areas being unequal areas; and,  
13      selectively providing actuating fluid under pressure to  
14      the first effective area or the second effective area to  
15      selectively pressurize injection fuel by the injection fuel  
16      pumping piston.

1       11.   The method of claim 10, wherein the first and  
2       second effective areas of the multi-stage intensifier

3     comprise respective areas of first and second intensifier  
4     pistons, respectively.

1           12.   The method of claim 10, wherein the first effective  
2     area comprises an area of a first intensifier piston, and the  
3     second effective area comprises an area of both the first  
4     intensifier piston and a second intensifier piston.

1           13.   The method of claim 10, further comprising  
2     selectively and simultaneously providing actuating fluid  
3     under pressure to the first and second effective areas to  
4     further selectively pressurize injection fuel by the  
5     injection fuel pumping piston.

1           14.   The method of claim 13, wherein selectively  
2     providing actuating fluid under pressure to the first  
3     effective area, the second effective area, and both the first  
4     and second effective areas comprises providing actuating  
5     fluid under pressure using two, two-position, three-way  
6     valves.

1           15.   The method of claim 10, wherein selectively  
2     providing actuating fluid under pressure to one of the first  
3     effective area and the second effective area comprises  
4     selectively providing actuating fluid under pressure to one

5 of the first effective area and the second effective area  
6 using a three-position, four-way valve.

1 16. The method of claim 10, wherein the actuating fluid  
2 is selected from the group of fuel, engine oil and hydraulic  
3 fluid.